MOTIVATION FOR EXPLORATION

EXPLORATION *is fundamental to the human spirit. Since the dawn of our species we have been explorers, with the motivation for these journeys ranging from survival to spiritual inspiration.*

With the rise of civilization, the search for new wealth and the elevation of national pride drove explorers to risk their lives and benefactors to empty their coffers in the quest for discovery. All of these factors — survival, inspiration, wealth, and national pride — provide the fundamental justification for proposing the most ambitious chapter ever in the history of human discovery of this planet: the exploration of Earth's oceans.

It has been stated many times that we know more about the backside of the Moon than we do about the bottom of our ocean. And that statement just refers to its depth. There exists on our planet, for example, a virtually unstudied ecosystem which rivals all the other known ecosystems on Earth — the mid-water environment in the oceans. This biologically rich and complex domain is known to contain many times the biomass of all the Earth's rainforests and terrestrial biota. Despite this area's size and importance, the biology of the organisms which inhabit the mid-water levels in the oceans, and the complex dynamics between this zone and the upper and lower levels of the ocean, are virtually unknown. We have just begun to learn about the diversity of life in all reaches of the ocean, and the cycling of its critical elements that support life and regulate climate. New physical processes that transport mass and energy await discovery, and most of the record of ancient Earth and human history contained in the cold sediment floor is still unread. To be sure, the United States has a superb record of basic and applied ocean research funded through a variety of federal agencies and private industry in support of U.S. national defense, weather prediction, resource assessments, and the testing of specific scientific hypotheses. What has been lost in this diverse research portfolio, however, is the opportunity to broadly explore on a global basis and across many scientific, cultural, and technological disciplines.

Fifty years ago, during the early days of modern oceanographic research, expeditions were exploratory. Ships were staffed with interdisciplinary teams of physical and chemical oceanographers, marine biologists, and geologists. The oceanographers made all conceivable measurements, secure in the knowledge that those observations would eventually prove worthwhile. Today, expedition personnel tend to be from a narrower range of disciplines, and ship time is allocated for measurements to test the hypothesis and carry out the objectives at hand, with little time left over for unrelated observations.

This Panel advocates a national program to permit exploratory expeditions for two reasons: ***1)*** The initial phase of oceanographic discovery ended before a significant part of the oceans were visited in even a cursory sense; and ***2)*** We now have marvelous new tools now that permit exploration in spatial and temporal dimensions that were unachievable 50 years ago. In other words, we will not only go where no one has ever gone, but we will also "see" the oceans through a new set of technological "eyes" and record these journeys for posterity.

What is Exploration?

For the purposes of this report, exploration is defined as discovery through disciplined diverse observations and the recording of the findings. An explorer is distinguished from a researcher by virtue of the fact that an explorer has not narrowly designed the observing strategy to test a specific hypothesis. A successful explorer leaves a legacy of new knowledge that can be used by

A MYSTERIOUS PLUME

In July 1986, while on a survey of hydrothermal vents on the Juan de Fuca Ridge off the Oregon coast, scientists from NOAA's Pacific Marine Environmental Laboratory began documenting elevated water temperatures at greater heights off the seafloor than ever previously recorded. Most plumes from hydrothermal vents along the Mid-Ocean Ridge rise only a few hundred meters before reaching temperatures of the surrounding water. However, in this case, the anomalous water was still much higher in temperature than the surrounding water at a height of more than 700 meters above the seafloor and the plume had spread out over an area that measured 20 km in diameter. A plume this size with this temperature was calculated to be the equivalent of approximately an entire year's worth of "normal" hydrothermal output from the ridge. However, when the ship returned to the same site a month later, no evidence of this "megaplume" was found. Scientists suspected that the culprit was a deep-sea eruption which is, by nature, a very short-lived oceanographic event. Subsequent studies of the seafloor in the region revealed the presence of very fresh lava and new hydrothermal venting stretching over tens of kilometers along the ridge. The unanticipated discovery of this deep-sea eruption provided a strong rationale for utilizing the Navy's SOSUS system in the area in 1991. The use of this system has led to the detection and intense study of three more seafloor eruptions and several other anomalous earthquake swarms that were essentially inaudible to land-based seismometers along the tectonic plate boundaries of the northeast Pacific basin.

THE ARCTIC OCEAN

The Arctic Ocean is the least explored of the world's oceans. Every voyage through the region, whether by ice-breaking vessel, surface expedition across the ice, or nuclear submarine under the ice, has yielded completely new knowledge and unexpected insights. The role of the Arctic region in global processes is not well understood. More information is needed to understand and predict how freshwater input, variability in sea-ice thickness, and the transport of heat into the Arctic Ocean, affect global climate. Future work in this area will require robust investigative tools and build on entirely new knowledge about the region.

In the summer of 1994, a remarkable expedition to the North Pole was conducted that generated several historic firsts. The expedition included the northernmost rendezvous ever of surface ships from the three largest Arctic nations: Russia, the U.S., and Canada, on August 23. The rendezvous occurred when American and Canadian ships that were the first surface vessels to cross the Arctic Ocean via the North Pole, joined the Russian ship. Significant findings from this expedition were the first observation of direct evidence of overall warming of the entire Atlantic layer, and the discovery of much higher levels of biological activity than previously assumed — from plankton to polar bears. The expedition was truly exploratory in that the findings were not predictable. Its rigorous scientific approaches enabled the new information acquired to advance understanding of the Arctic and paved the way for future scientific exploration and research.

With the Arctic covered by ice much of the year, scientists have never been able to accurately measure the temperature of this vast ocean. A newly emerging technique, using sound sources and arrays of receivers, may finally change that. Initial results have shown that the Arctic Ocean has warmed more dramatically than climatologists had predicted. Clearly, the discoveries in this region demonstrate that the Arctic is ripe for future exploration.

those not yet born to answer questions not yet posed at the time of the exploration. This new knowledge may also have immediate beneficial applications in answering the needs of contemporary ocean scientists, natural resource managers, educators, and industries.

New discoveries come about both in the context of directed, hypothesis-driven research and in the process of pure exploration. Research journals and Nobel prizes give testament to the numerous cases of serendipitous discoveries stumbled upon in the course of directed research undertaken for completely different reasons. Several examples of this sort of fortuitous discovery are described in sidebars contained within this report. The Panel advocates continuing the basic and applied research undertaken by many federal agencies, and in addition, proposes adding a new program in ocean exploration that will expand scientific investigations into new areas. Answering questions and following up on ideas will still be cornerstones of the new program. While hypotheses may be less specific, and their outcome less predictable, than the current norm, the observations will be more broadly based, and the program more interdisciplinary. The potential for payoffs from this endeavor will be enormous.

Characteristics of a U.S. Ocean Exploration Program

The U.S. will greatly benefit from a renewed commitment to exploration. A modern exploration initiative should be designed with the following desirable characteristics in mind.

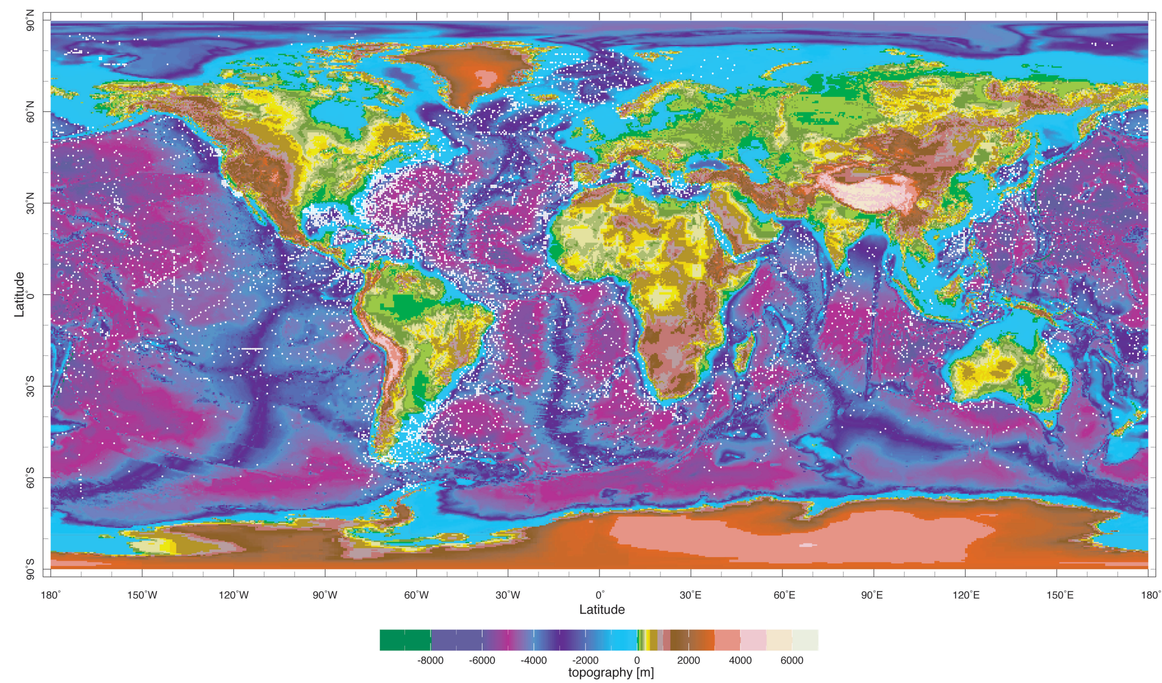
— **DISCOVERY AND THE SPIRIT OF CHALLENGE SHOULD BE CORNERSTONES.** *The tendency in oceanographic research in recent years has been to return again and again to areas visited before as scientific hypotheses become increasingly refined. The emphasis in exploration will be to survey new areas to provide baseline information that may well inspire future hypothesis-driven research.*

— **EACH FACET OF EXPLORATION IS NECESSARILY MULTIDISCIPLINARY** *and should include aspects of the natural sciences, social sciences, and artistic expression. Disciplines that are historically under represented in ocean exploration and can bring to bear new concepts*

LAMONT cores

In the 1950s and 1960s, during the reign of Maurice ("Doc") Ewing at Columbia University's Lamont-Doherty Earth Observatory, Lamont's vessels were under strict orders to stop every day at noon to take a sediment core, no matter where the ship was or what else it was doing. Doc did this purely in the spirit of exploration, understanding that we knew so little about the seafloor and ocean history that a global core database would inevitably be of value. "Value" has turned out to be an understatement. This core database (core locations shown as white dots in figure) has become the foundation of our understanding of climate change mechanisms. A core taken by the vessel *Robert Conrad* in 1967 recorded a particularly complete and high- resolution record of changes in benthic and surface biota over the last 250,000 years.

Nearly a decade later, the pioneering work of John Imbrie, Jim Hays and Nick Shackleton used the cyclic variations found in this core to substantiate the Milankovitch Hypothesis. This hypothesis puts forward the theory that the waxing and waning of ice ages can be attributed in part to variations in orbital parameters that occur at periods of 19, 22, 41, and 100 thousand years. The Lamont core suite also provided the early scientific basis for motivating the Deep Sea Drilling and Ocean Drilling programs. This example of routine data collection that leads to discovery has been repeated frequently over the past 50 years of oceanographic data collection and underscores the importance of the full utilization of existing data sets and serendipitous discoveries in the oceanographic sciences.



and rich experiences should be challenged to participate.

— **THE OCEAN EXPLORATION PROGRAM SHOULD INCLUDE AN EDUCATIONAL COMPONENT** *that encompasses both formal and informal educational institutions as well as the general public. These efforts should incorporate existing programs and organizations that support marine and ocean science education.*

— **THE OCEAN EXPLORATION PROGRAM SHOULD CONSIDER ALL THREE DIMENSIONS OF SPACE, AS WELL AS THE FOURTH DIMENSION OF TIME.** *Exploration must go beyond mapping the seafloor. It cannot ignore the fact that the ocean is forever changing in time, and that human impacts are already substantial. Explorations into all four dimensions will also challenge our knowledge of scales of variability. For example, previously unknown microbial phenomena may yield discoveries as grand as those resulting from basin-scale explorations. Resolving picosecond variability may prove to be as challenging as exploring the changes observed over millennia.*

— **THE OCEAN EXPLORATION PROGRAM SHOULD BE GLOBAL IN SCOPE BUT CONCENTRATED INITIALLY IN REGIONS UNDER U.S. JURISDICTION.** *This focus will provide the best opportunities for immediate benefit to the American people, while controlling the use of national resources and protecting valuable marine life and habitats under U.S. management authority*

— **THE RESULTS OF THE EXPLORATIONS MUST BE CAREFULLY DOCUMENTED** *using the latest in database technology, communications, and recording media. The documentation should take a variety of forms, from the archiving of digital data to the production of multimedia programming and other educational resources and tools for the public.*

— **THE RESULTS MUST BE WIDELY DISSEMINATED,** *through a variety of formats, and particularly the Internet, to reach a large number of potential beneficiaries. Shipboard activities should be available in near real-time to enhance the outreach opportunities provided by a program of this scope and visibility. The results should excite the public imagination as well as challenge and encourage public involvement.*

— **THE OCEAN EXPLORATION PROGRAM NEEDS EXPLORERS, CHAMPIONS, AND ROLE MODELS** *who may not themselves directly benefit from the data being collected. The "human element" is essential to humanize the science and provide role models for future explorers.*

— **THE OCEAN EXPLORATION PROGRAM SHOULD MAKE EVERY ATTEMPT TO WORK WITH INTERNATIONAL PARTNERS** *when appropriate. This is essential for work in waters under the jurisdiction of other nations and will serve to expand the program and leverage its resources in international waters.*

— **THE OCEAN EXPLORATION PROGRAM SHOULD CAPITALIZE ON JOINT OPPORTUNITIES WITH OTHER COMPATIBLE GOVERNMENT MISSIONS AND INDUSTRY** *where appropriate. For example, survey missions of NOAA's nautical charting program, the U.S. Geological Survey, and the Oceanographer of the*

Navy can substantially contribute to ocean exploration. Joint planning and funding of these missions should be made when mutually beneficial.

— **THE OCEAN EXPLORATION PROGRAM MUST BE SYSTEMATIC IN ITS COLLECTION OF DATA,** *to facilitate the joint interpretation of data collected at different times and in different places. A systematic program will also help to avoid duplication of effort.*

— **THE OCEAN EXPLORATION PROGRAM SHOULD CHALLENGE EXISTING TECHNOLOGY.** *Just as space exploration has become a leading arena for technology development and transfer, ocean exploration must use the latest capabilities and should provide an incentive for creating new tools. Technology partnerships with the petroleum and oil service industries could, for example, tap into their already massive investments in deep-water and ocean technologies. All technologies should be brought to bear — human occupied submersibles: remotely operated vehicles (ROVs); and autonomous underwater vehicles (AUVs); platforms under, on, and above the sea surface; advanced sensor technologies; and information storage and transfer technologies — to meet the challenges of the years to come.*

— **ALL STAKEHOLDERS IN THE OCEAN EXPLORATION PROGRAM MUST BE ENCOURAGED TO ACCEPT RISKS WHERE BENEFITS ARE LARGELY UNKNOWN.** *It is possible that the technology might not work, and that objectives might not be achieved within the specified timeframe. Nevertheless, exploration should be considered a success regardless of what is discovered.*

The Ocean Exploration Program must be innovative and bold. "Business as usual" will not achieve the goals.

The Fruits of Exploration

Experience has shown that observations from the oceans are eventually put to myriad uses. They result in scientific, cultural, and historic understanding of how our planet functions, who we are, and how we got where we are today. The beauties and mysteries of the oceans inspire artists, authors, and musicians. We cannot protect what we do not know, and thus, without ocean exploration, we are ignorant of what needs to be conserved in a realm that covers most of the surface of the Earth. The ocean provides a bounty of renewable resources, but without knowledge of what's out there, how abundant it is, and how quickly it is replenished, we cannot plan for its environmentally sustainable use. We also know that the oceans provide a storehouse of non-renewable mineral resources essential for maintaining our quality of life, though much of that wealth remains undiscovered. Every day, governments make decisions on how to best regulate the use of the oceans, yet they lack the basic knowledge to make informed choices. Accurate knowledge of the oceans is essential for environmental, economic, and national security. Designing and building platforms and observing systems for the extremely demanding and unforgiving ocean environment pushes our technology to its limits and leads, more often than not, to commercial spin-offs.

Despite the fact that we can confidently predict that ocean exploration will lead to discoveries that directly benefit the nation, it is impossible to predict when we embark upon the voyage of discovery exactly how that benefit will be manifest. Today, we may discover a new organism with enzymes that render inert a particular environmental carcinogen, or tomorrow, we may learn more about the mechanisms that triggered a catastrophic global warming and led to mass extinctions many millions of years ago. Discovery is the prelude to new paradigms; it jolts us out of the ruts of incremental scientific progress and fuels the great leaps forward.

UNITED STATES DEPARTMENT OF ENERGY EXPLORATION AND PRODUCTION PARTNERSHIP

Nearly one-third of today's U.S. gas supply and one-quarter of the nation's oil come from the ocean coastal zones and continental shelf. Exploring for and producing these resources has steadily moved into ever-deeper waters — from a depth of 300 feet 30 years ago to 6,000 feet today, with future plans to explore new depths below 10,000 feet tomorrow. Thus, there is an ever-increasing demand for advanced technologies that will facilitate the economic, safe, and environmentally benign production of underwater oil and gas resources.To help achieve that goal, DOE through the Exploration and Production Program will partner with industry, academia, national laboratories, and other agencies. For example, DOE is initiating a partnership with industry, for testing of an ocean-floor module for production of oil and gas. If successful, this technology will provide much greater access to underwater oil and gas resources at a lower cost, and it will provide an opportunity to gain knowledge of the sea-floor and its ecosystems. Exploration programs will benefit, particularly those involving methane hydrates—ice-like cages of water molecules containing methane on the ocean floor and below. They have a resource potential estimated to exceed all other oil, gas, and coal resources. The technology will also enhance our understanding of how the oceans affect the Earth's carbon cycle and the causes of global climate change.